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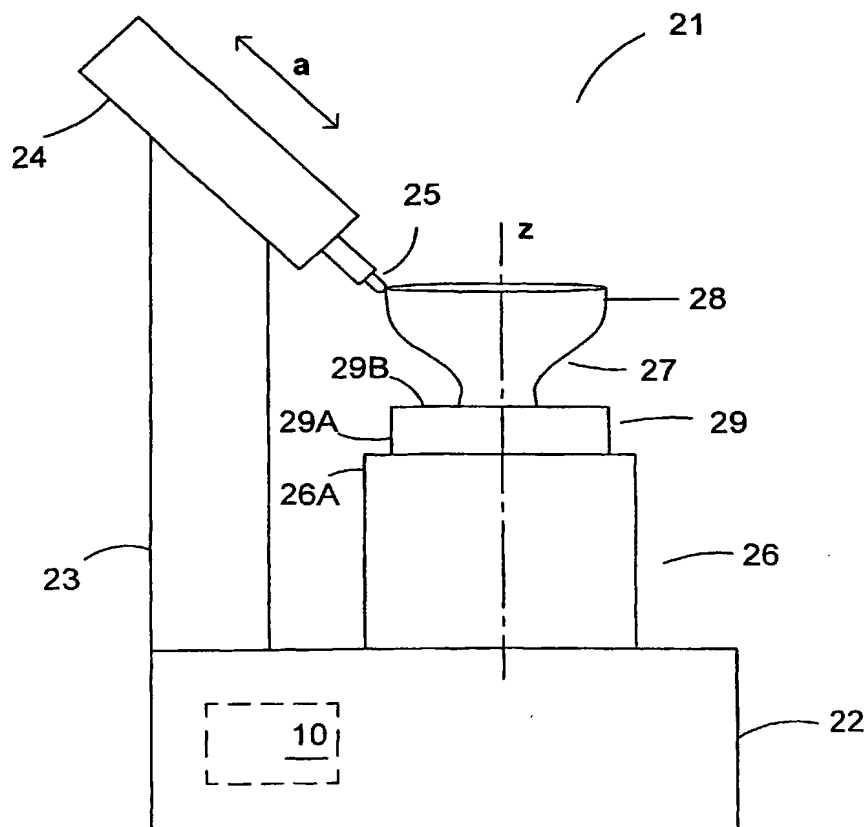11 March 2004 (11.03.2004)

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(54) Title: METHOD OF SCANNING

(57) Abstract: A method of scanning an object is disclosed comprising the steps of providing a scanning device having a probe and a sample holder whereby the sample holder is rotatable relative to the probe, providing a first feature for indicating the start and/or end of a scan, and recognising the first feature whereby when the first feature is recognised the scanning device is ready to start or end a scan. The scanning device may have a fixed stop which comprises the first feature alternatively, the first feature is provided on the scanning device or on the object. A second feature, located on the scanning device or object for example, may be provided wherein the first feature indicates the start of a scan and the second feature indicates the end of the scan. Also disclosed is an apparatus for scanning an object.

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METHOD OF SCANNING

This invention relates to a method of scanning an object.

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One method, which may be used with circular or helical scans, is to begin the scan at a manually determined position and end the scan when the distal end of the object is reached, perhaps determined when the

10   rotational axis is reached. A problem with this method is that it can require complicated set-up to ensure that the whole object surface is scanned which is time consuming.

15   According to a first aspect of the present invention there is provided a method of scanning an object comprising the steps of:

providing a scanning device having a probe and a sample holder whereby the sample holder is rotatable

20   relative to the probe;

providing a first feature for indicating the start and/or end of a scan; and

recognising the first feature whereby when the first feature is recognised the scanning device is

25   ready to start or end the scan.

The first feature is recognised by a control device provided in the scanning device or connected thereto.

30   In a preferred embodiment, the scanning device has a fixed stop which defines a known relationship between or relative position of the probe and sample holder. Preferably, the fixed stop comprises the first feature. Thus, when the scanning device is at the fixed stop,

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the first feature is recognised i.e. the fixed stop
constitutes the start or end of a scan.

In one embodiment, the fixed stop is returned to after
5   the completion of a scan, or when the scanning device
is switched on therefore, the fixed stop denotes the
start of a scan. In this embodiment, once the sample
is located on the sample holder, mere verification that
the parts of the scanning device are at the fixed stop
10   is necessary for recognition of first feature.

When the first feature indicates the start of a scan
and, on recognition of the first feature the scanning
device is ready to start a scan, the method preferably
15   further comprises the steps of providing a second
feature for indicating the end of the scan and
recognising the second feature whereby when the second
feature is recognised the scanning device is ready to
end the scan.
20
The method according to the invention allows automatic
determination of the start and/or the end of a scan and
thus enables semi or unmanned operation and potentially
automatic start up/switch-off of motor drives used in
25   the scanning process.

According to a second aspect the invention provides an
apparatus for scanning an object comprising:
         a scanning device having a probe and a sample
30   holder whereby the sample holder is rotatable relative
to the probe; and
         a control device for controlling relative motion
between the probe and sample holder and for recognising
a first feature whereby the control device starts

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and/or ends a scan on the basis of recognising the
first feature.

Preferably, the control device includes a computer
5   programme which recognises the first feature.

According to a third aspect the invention provides a
computer programme for use with a scanning device
having a probe and a sample holder whereby the sample
10   holder is rotatable relative to the probe and whereby
the computer programme includes recognition information
indicative of a first feature whereby the computer
programme compares data from a scanning procedure with
the recognition information and when the data
15   substantially coincides with the recognition
information the programme signals the start or end of a
scan.

The recognition information may be as simple as a
20   contact occurring between the probe tip and a surface
within a certain plane; or the probe tip reaching a
defined co-ordinate; or the probe tip movement
describing a certain profile.

25   The invention will now be described by way of example
and with reference to the accompanying drawings, of
which:
       Fig 1 shows a scanning device which is suitable
for use with the method of the invention;
30   Fig 2 is a flow diagram showing different steps
according to an embodiment of the invention;
       Fig 3 shows a cross section through an object
suitable for being scanned according to the invention;
and

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Fig 4 shows diagrammatically how data from a scan
is selected.

Fig 1 shows a scanning device 21 having a base 22 and a
5   back portion 23 which has an LVDT probe 24 attached
thereto. The probe has a scanning tip 25 which is
movable along an axis designated by the letter a in
this case axis a is at 45° to a vertical axis z.
Mounted on the base 22 is a sample holder 26 onto which
10   an object 27 may be placed for scanning. The object 28
may be located in a fixture 29 prior to being mounted
on the sample holder 26. The probe 24 and the sample
holder 26 are relatively movable along axis z and the
sample holder 26 is rotatable about axis z. The
15   scanning device 21 includes a control device 10 for
controlling the relative movement of the probe 24 and
sample holder 26.   ·

In one embodiment, a start (or first) feature is
20   provided by or on the sample holder, for example, it is
provided by the side surface 26A of the sample holder
26. If a fixture 29 is used, the side 29A or upper
surface 29B could provide the first feature. In these
cases, it is advantageous if the sample holder 26 and
25   fixture 29 are circular in cross-section as it can then
be established where along both the z and a axes the
particular feature lies. This in turn enables the
probe tip 25 to move rapidly towards the first feature
then, on deflection of the probe tip at an expected co-
30   ordinate the start feature is recognised and, the probe
movement is either paused or changed enabling motion
according to a predetermined scanning routine. Pausing
the motion enables an operator to double check that the
feature has been found, or allows for stabilisation of

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external influences such as thermal conditions.

Advantageously, the scanning device is designed such
that when it is at a fixed stop, the probe
5   automatically encounters the start feature. The device
is programmed to return to a fixed stop at the end of a
scan and the relative position of the probe tip and
sample holder at this fixed stop is manipulated so that
when a fixture or sample is located on the sample
10 holder, the probe tip is located at or on the first
feature ready to begin the scan. In order to
facilitate location of a sample or fixture on the
sample holder, either the probe is retracted away from
the sample holder or, the sample slides into position
15 on the sample holder. When a scan is initiated, the
position of the vertically movable part of the device
is confirmed along with the probe tip reading. If both
these readings indicate that the probe tip is in
contact with the first feature, the device is ready to
20 begin to scan the object.

Once the scan has started, the sample holder and probe
move relatively along the z-axis. The probe follows a
helical or spiral path along the sample surface until
25 the sample has been scanned. At this point, as it
meets no resistance, the probe tip moves towards the
rotational axis of the sample holder. The second
feature may thus be defined as the probe reaching the
rotational axis (z) of the sample holder.
30

Alternatively, a start feature may be provided by the
sample. Referring now to Fig 4, the sample 30 is solid
i.e. does not have a hollow centre. In this case, the
start feature 32 is provided by the surface of the

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sample which is distal to the sample holder or fixture
(not shown). It is convenient that the sample is
located approximately centrally on the rotational axis
of the sample holder. The probe tip is simply located
5   on the rotational axis at a set height above the sample
holder. The probe tip and/or sample holder are moved
towards each other until the tip contacts the sample.
This contact causes a deflection of the probe tip on
the rotational axis of the sample holder which
10   designates the first feature thus, the start feature is
recognised and the probe is ready to start a scan.

In a further embodiment, the start feature is provided
at a set height (or co-ordinates) above the sample
15   holder. In this embodiment, the scan is initiated
prior to contact between the sample and probe tip which
allows for rapid relative movement of the probe and
sample holder to a location close to the contact point
(the set height) and safeguards the probe from damage
20   which can occur if it contacts a surface whilst moving
quickly.

The second feature, which denotes the end of a scan may
be provided by the sample holder, fixture or sample.
25   When the second feature is recognised, by reaching
certain co-ordinates or the probe tip describing a
certain characteristic shape, the probe moves rapidly
to a standby location to await further instructions.

30   When the scan starts at or near the top of a sample,
the probe tip moves towards the sample holder during
the scan. If the sample, fixture or sample holder has
a certain characteristic profile, this can be used as
the second feature (see Fig 2 for a more detailed

explanation).

For example, if the sample holder has a known diameter,
the second feature could be the reaching of an a-axis
5   coordinate that relates to this diameter. An actual
physical feature such as a lip to the sample holder or
the fixture could also be provided creating a more
complex first feature which provides greater assurance
that the feature is recognised.
10

Alternatively, a datum stop may be used for the second
feature. Before starting the scan, the relative
positions of the probe and object at the end of the
scan are established in the z-direction. The probe is
15 then either returned to the start position (if it has
been previously recognised) or, instructed to find the
start of the scan, the object is then scanned until the
z-axis location at the end of the scan is reached, at
which point the scan is complete.
20

If a fixture is used, it is important that the sample
sits sufficiently proud of the fixture so that all of
the sample surface that is required can be scanned.

25 Fig 2 shows a flow diagram which details the different
steps of an embodiment of the invention.

A start of the scanning process 100 is located as
described previously with respect to Fig 1.
30

The scan is initiated 200 and the probe and object are
moved relatively along the scan line. Data is selected
300 from the scan and optionally stored 400. The
selected data is then analysed 500 and compared with

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criteria 600 or recognition information which determine
when the scan ends 700. Until the criteria are met,
the scan and data collection continues 800. When the
criteria are met, the control device recognises the
5   second feature and is ready to end the scan. These
steps are carried out within the scanning device or, in
a separate controller.

This embodiment will be discussed in relation to the
10   surface of a sample which is distal the sample holder
being the first feature, thus the start is defined as
lying on the centre of rotation of the sample holder
26. The person skilled in the art will appreciate that
the other start positions discussed are alternatives.
15

The object 27 should to be aligned on the centre of
rotation with a reasonable degree of accuracy as the
probe has a zone in which it will be most accurate
which tends to be away from the limits of its motion;
20   the processing means which converts data points from a
scan into a three-dimensional model often uses the
rotational axis as a reference so analysis of selected
data is simplified; and the stability of an object on
the sample holder is increased. A certain amount of
25   misalignment, for example if an object is centred by
eye, will not affect the accuracy of results indeed, an
object may be placed near the circumference or edge of
the sample holder however, this is less desirable.

30   For the purposes of one embodiment for determining the
end of a scan the absolute position along the
rotational axis is not important, however the
relationship of different pieces of data on this axis
is important as will be described later.

Next, the scan 200 of an object 27 begins. Various
data points which are captured during the scan are
selected 300 based on predetermined requirements and
5   analysed. The selected data 300 may be temporarily
stored until the scan is complete. If the start point
is considered as the centre of the circle lying in a
plane perpendicular to the z-axis then, for example,
one data point for every 10° of rotation around that
10   circle may be selected however, this may be increased
to every degree or two data points per degree if
required. All data captured during the scan could, in
theory, be selected but this may increase processing
time for determining whether the end of the scan has
15   been reached.

As the scan continues, data points which are from the
same orientational direction are stored in association
with each other such that their relative positions
20   along the z axis are maintained. For example, this
could be as a table with the orientational direction
along one side and the order of data capture along the
other. In this manner, a plurality of splines of data
are created.
25

The data points once stored are analysed 500 and
compared with previous data within the set to determine
if the criteria have been met 600. This occurs during
the scanning process to enable automatic determination
30   of the end of the scan without post-processing of the
data. As the data points within a set all lie on an
orientational direction the (x,y) coordinates of the
data points can be converted into a distance from the
origin on that direction (a radial distance). Changes

in this distance reading or even when the distance
becomes constant are used to set the criterion for
whether the end of a scan has been reached.

5   Referring to Fig 1, if the scan begins at the bottom of
the object 27 i.e. at the surface of the sample holder
26 or fixture 29 if used, the criteria for the end of
scan would be when the distance remained constant for
two data points within each set, i.e. when the probe
10   tip 5 had reached point 28. The fact that the distance
had decreased and subsequently increased earlier on in
the scan is not important in determining the end of the
scan.

15   If the scan began at the top of the object 27 a
suitable criteria would be when the data sets increased
on two subsequent rotations following a minimum
distance from the origin being attained.

20   The criteria for determining the end of a scan may be
set as any number of completed circles which lie in a
plane perpendicular to the z-axis achieving either the
desired change or consistency of distance from the
origin. Certainly at least two is recommended in order
25   that the surface deviations do not cause premature
cessation of a scan. Also, due to non-symmetry of some
objects, it is preferred that criteria are set which
includes that compliance of a certain number of the
data sets with the distance criterion is required. For
30   example when 95% of the sets of data meet the distance
criteria as otherwise a scan could continue
indefinitely and require manual termination.

Once the criteria have been met, the scan is complete

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700. Reaching the end of the scan could be used to
trigger a return to a stand-by position for the probe
and sample holder followed by switching off the motors
that control the relative motions during the scan. Of
5   course, for the device 21 of Fig 1, the scan could be
controlled by a single motor in which case the sample
holder would describe a helical path during the
scanning process. Alternatively, the probe remains at
the complete location for operator verification that
10 the scan is complete.

As an alternative to determining the change or
consistency in distance of the data for each
orientational direction from the origin or when a
15 change in direction of this distance has occurred, the
information could be used to determine the change in
gradient of the slope of each spline. A person skilled
in the art would appreciate that there are other
techniques that can be used.
20

Fig 3 shows a cross section through a turbine blade 30
which will undergo a scanning process according to the
invention. As the turbine blade 30 is scanned (not
shown) data points from certain predetermined
25 orientational directions from the defined origin of the
scan are selected from all the data captured during the
scan. Referring now to Fig 4, these splines of data
can be visualised as being lines of longitude 31 on the
surface of a globe which has the location of start of
30 scan at a pole.

Analysis of the data produces a distance measurement
from the origin or start which is compared to previous
measurements in that data set and the criteria of an

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end of scan to determine whether such an end has been
reached.

5   For certain objects which have irregular shapes, it can
be difficult to mount the object on a sample holder in
such a way that all parts of the surface of the object
are accessible during scanning. This is illustrated by
an undercut 34 which does not allow the probe tip 36 to
accurately scan this part of the blade 30 as the tip 36
10 is prevented from touching the surface by an overhang.

This problem is also encountered in samples having re-
entrant points, for example, where there is a hollow in
the surface. The re-entrancy or hollow could be
15 undetected, resulting in an incomplete scan. This
would mean that an article manufactured based on the
scan would be inaccurate and possibly unusable. If
however, during the scan, selected data points are
collected and analysed by, for example conversion to
20 distances from the origin along splines (see Fig 4
reference number 31), re-entrant points or hollows
which are of a significant size (greater than the size
of the probe tip) can be identified during the scan
enabling realignment of the object immediately. This
25 is because the re-entrant region would show up as a
reduction in the distance from the origin and is likely
to occur for a number of selected data points and for a
number of rotations of the sample holder. Thus, there
would be an inconsistency when compared with other data
30 proximate to that region. It is unlikely that such a
re-entrancy would stop a scan as less than the
proportion of data sets required would meet the
criteria but it could be indicated to an operator as a
potential problem. One way this could be achieved is

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by visualising the splines of data on a monitor, the
colour could change when a change in direction of the
distance is detected.

5   If such a re-entrant point is detected then the scan
may be stopped for realignment of the object or if it
is not discovered until the end of the scan the
operator could, by quickly checking the results,
establish that a point of re-entry did occur and redo
10   the scan thus preventing manufacture of inaccurate
components.

Referring now to Fig 3, the end of a scan which starts
at or near the top of the blade would be defined by the
15   criteria that 90 or 95% of the sets of data would go
through a maxima of radial distance from the origin
followed by a reduction to a constant distance, i.e.
the distances of data points gradually increases then
decreases and finally holds steady for a number of
20   revolutions of the sample holder. At this point, the
scan has reached the foot portion of the blade.

The invention can be applied to the scanning any of
object for the purposes of producing a reproduction or
25   digital representation thereof, examples include
objects used in aerospace, transport, medical
applications such as replacement joints and dentalware
(for example copings), furniture, containers such as
bottles and leisure goods.
30
Although the examples have been described using a
contact scanning device, the invention is equally
applicable to use with non-contact devices such as
laser probes. In this case, in addition to the above

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described features, marks having different optical
properties to surrounding material could be used.

The use of features as hereinbefore described enables
5   automatic start and optionally an automatic termination
of a scanning procedure without time consuming and
difficult machine set up.

15

CLAIMS

1.   A method of scanning an object comprising the steps of:

5   providing a scanning device (21) having a probe (24) and a sample holder (29) whereby the sample holder is rotatable relative to the probe;

providing a first feature for indicating the start and/or end of a scan; and

10   recognising the first feature whereby when the first feature is recognised the scanning device (21) is ready to start or end the scan.

2.   A method according to claim 1 wherein, the
15 scanning device (21) has a fixed stop which defines a known relationship between the probe (24) and the sample holder (26). .

3.   A method according to claim 2 wherein, the fixed
20 stop comprises the first feature.

4.   A method according to claim 3 wherein, the fixed stop indicates the start of a scan.

25 5.   A method according to claim 1 or claim 2 wherein, the first feature is provided on the scanning device (21).

6.   A method according to claim 5 wherein, the
30 scanning device further comprises a fixture (29) for at least partially housing an object.

7.   A method according to claim 1 or claim 2 wherein, the first feature is provided on the object (27,30).

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8.   A method according to claim 1 or claim 2 wherein,
the first feature indicates the start of a scan and on
recognition of the first feature the scanning device
5   (21) is ready to start a scan and the method further
comprises the steps of:
        providing a second feature for indicating the end
of the scan; and
        recognising the second feature whereby when the
10   second feature is recognised the scanning device (21)
is ready to end the scan.

9.   A method according to claim 8 wherein, the second
feature is provided on the scanning device (21).
15

10.   A method according to claim 9 wherein, the
scanning device (21) further comprises a fixture (29)
for at least partially housing an object.

20   11.   A method according to claim 8 wherein, the second
feature is provided on the object.

12.   A method according to claim 8 wherein, the second
feature comprises a datum stop.
25

13.   A method according to claim 1 wherein, a scan
automatically starts or ends when the scanning device
recognises the first feature.

30   14.   A method according to any of claims 8 to 12
wherein, a scan automatically ends when the scanning
device recognises the second feature.

15.   An apparatus for scanning an object comprising:

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a scanning device (21) having a probe (24) and a sample holder (26) whereby the sample holder is rotatable relative to the probe; and

5   a control device (10) for controlling relative motion between the probe and sample holder and for recognising a first feature whereby the control device starts and/or ends a scan on the basis of recognising the first feature.
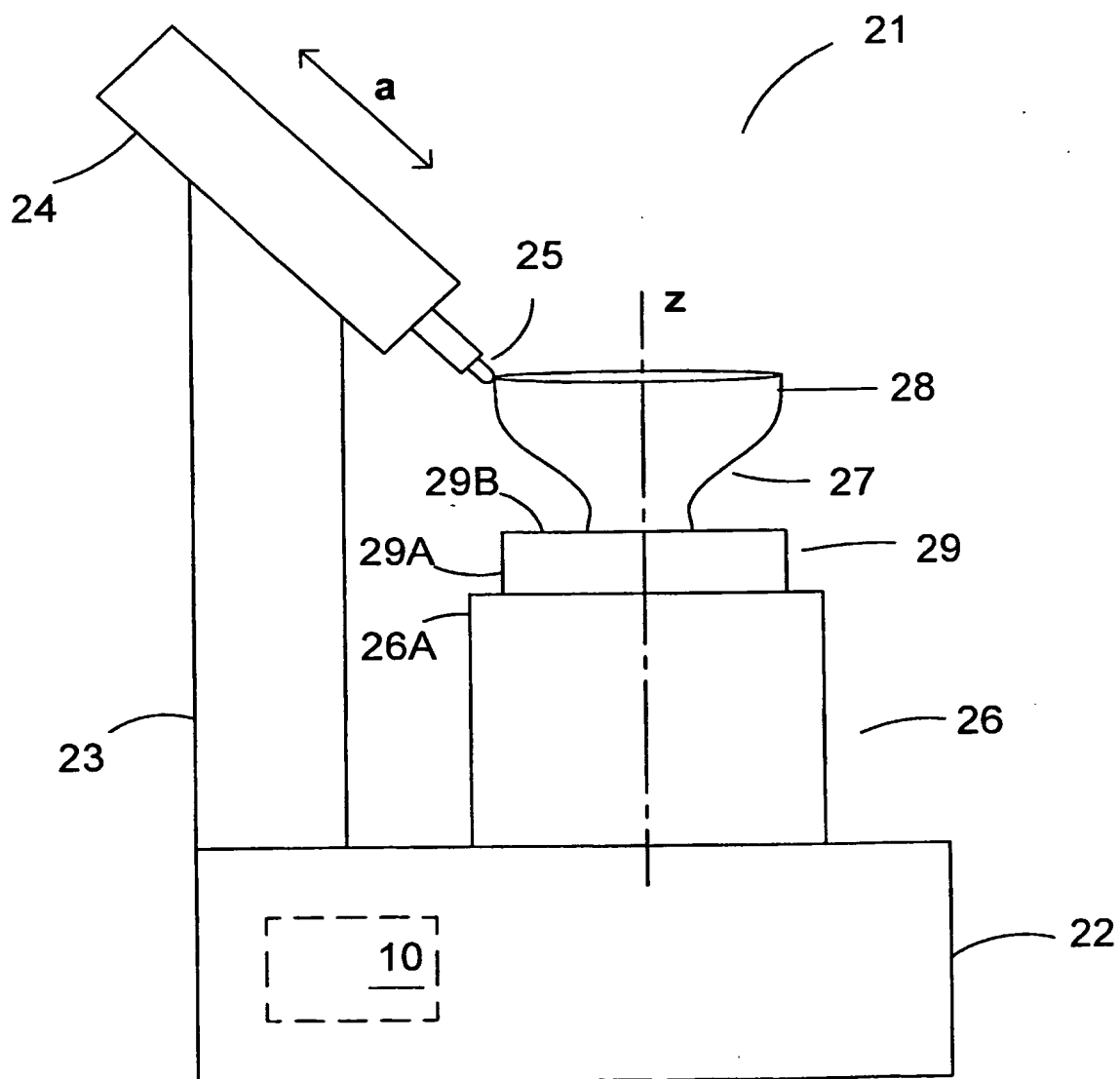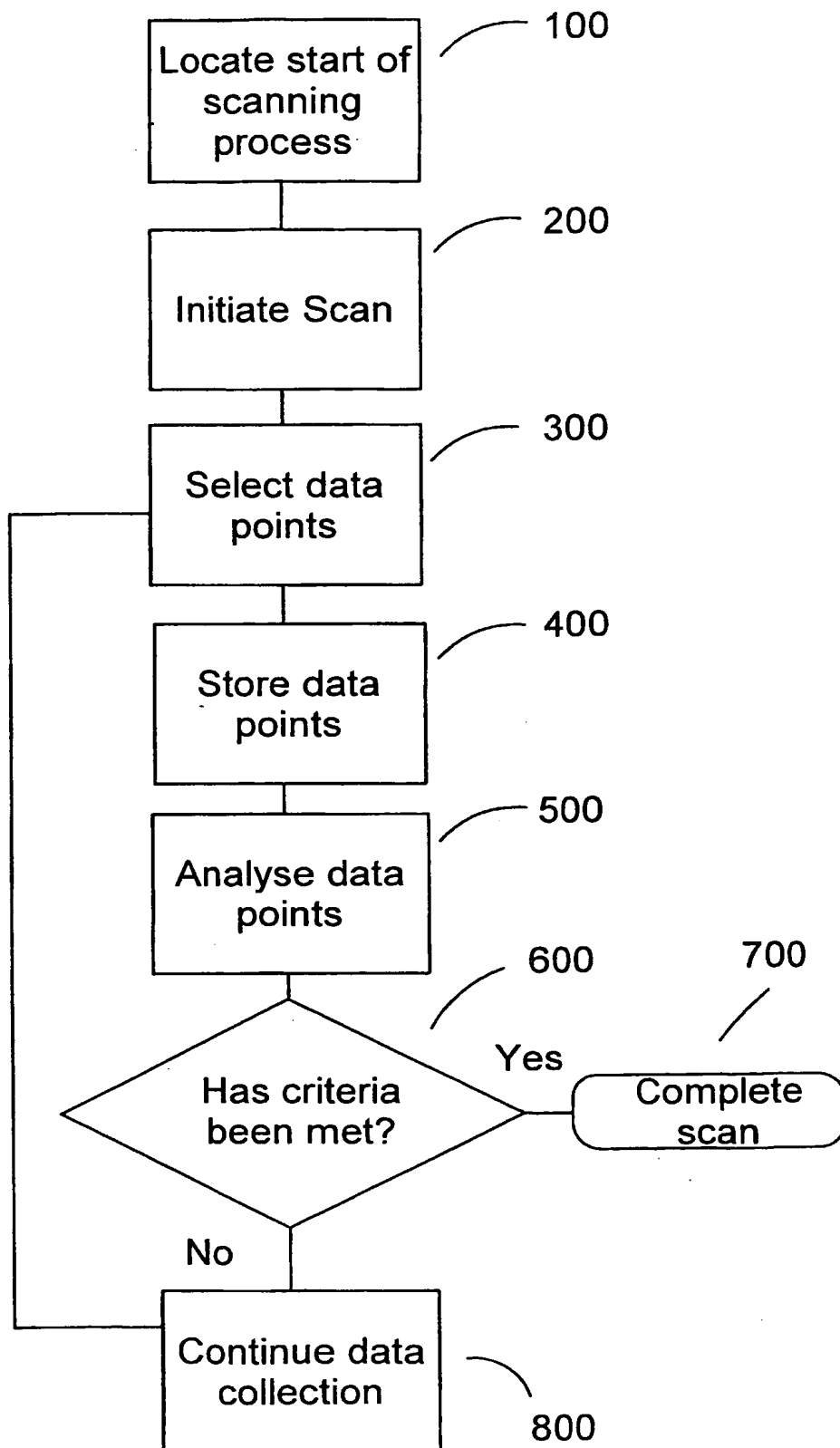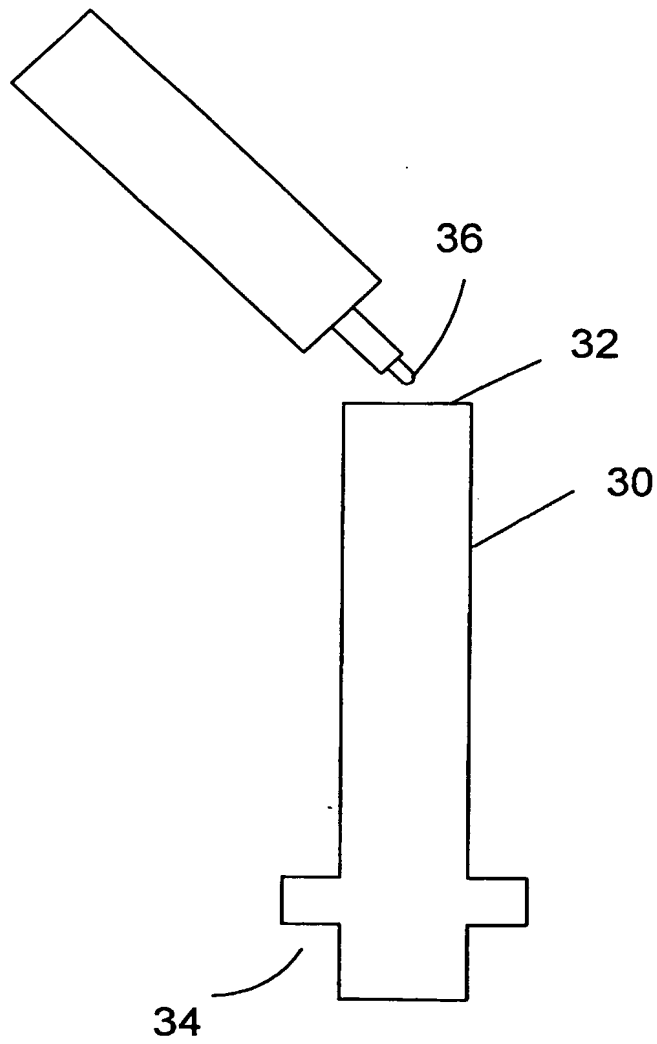
Figure 1

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Figure 2

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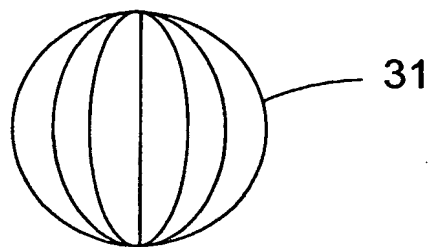30

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Figure 3

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Figure 4